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RATE- AND DURATION-OF-LOAD BEHAVIOR OF LAB-MADE  
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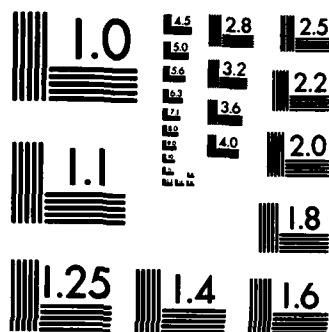
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# Rate- and Duration-of-Load Behavior of Lab-Made Structural Flakeboards



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**Abstract**

Tests of structural use panels under different loading conditions provide basic information for establishing design stresses. This paper reports the effects of loading rate in tension and bending and of duration of load in tension on the properties of four lab-made structural flakeboards, (two of which had aligned flakes). The objective was to determine if these panels—made from larger, engineered flakes—behaved the same as commercial particleboards—made primarily from planer shavings and sawdust—that were evaluated in an earlier study. For specimens loaded to failure at different rates of deformation, strength decreased 12 pct in tension and 8 pct in bending with each tenfold increase in time to maximum load. Modulus of elasticity decreased 4 to 5 pct. For specimens loaded in tension at constant stress levels from 50 to 90 pct of static strength, time to failure increased tenfold with each 8 pct decrease in stress. These results for the lab-made structural flakeboards are essentially the same as those reported earlier for commercial particleboards.

Keywords: Flakeboard, stress-rupture, particleboard, rate of loading, duration of load, tension, bending

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## Introduction

Information on structural flakeboard behavior under different loading conditions is necessary for developing design stresses. Two important conditions are rate at which load is applied and length of time load remains in place. Earlier studies (McNatt 1975, 1978) determined the rate- and duration-of-load behavior of commercial particleboards made primarily from planer shavings and sawdust. The objective of this study was to determine if structural flakeboards made from larger, engineered particles (flakes, wafers, strands) reacted in the same way to the various loading conditions.

## Research Material

Four different 1/2-in-thick, lab-made flakeboards, all bonded with phenolic-resin adhesive, were evaluated in this study. Basic properties of the boards (table 1) were determined in an earlier study (Geimer, Lehmann, and McNatt 1974), and board type numbers used below correspond to those used in that study.

The construction of the four types of flakeboard is shown in table 1. The core material in board type 7 is the same as the face material in board type 4. The material in board type 8 is the same as the face material in board type 7. The materials in board type 7 and 11 are the same, except that the face flakes are aligned in board type 11.

Raw materials for all board types were forest residues, primarily Douglas-fir, from Washington and Oregon. For board types 4, 7, and 11; face:core:face weight ratio was 15:70:15.

Table 1.—Bending and tension properties of four lab-made flakeboards<sup>a</sup>

Board type	Face material	Core material	Specific gravity	Bending		Tension		Test direction <sup>b</sup>
				Modulus of elasticity	Modulus of rupture	Modulus of elasticity	Tensile strength	
				K lb.in <sup>2</sup>	lb.in <sup>2</sup>	K lb.in <sup>2</sup>	lb.in <sup>2</sup>	
THREE-LAYER RANDOM								
4	1-in ring flakes <sup>c</sup>	Planer shavings	0.67	504	3,220	364	1,600	
7	2-in disk flakes <sup>d</sup>	1-in. ring flakes	.67	842	5,430	539	2,360	
HOMOGENEOUS, ALIGNED								
8	2-in disk flakes	2-in disk flakes	.65	1,696	8,650	1,554	4,860	Parallel
			.65	142	900	68	250	Perpendicular
THREE-LAYER, FACE FLAKES ALIGNED								
11	2-in disk flakes	1-in ring flakes	.68	1,598	8,100	1,081	3,100	Parallel
			.65	267	2,020	268	1,190	Perpendicular

<sup>a</sup>Taken from table 1 in Geimer, Lehmann, McNatt 1974.

<sup>b</sup>Relative to flake alignment.

<sup>c</sup>1-inch chips flaked to 0.020-in thickness in ring flaker.

<sup>d</sup>1 2-in blocks flaked to 0.020-in thickness and 1/2-in width in disk flaker.

## Research Methods

Specimens for rate of loading tests (bending and tension) and duration of load tests (tension) were cut from 22- by 26-in panels remaining from the previous study (Geimer, Lehmann, McNatt 1974) of basic properties—5 or 6 panels of each type. Because of the limited material, not all board types were tested under all loading conditions. All tests were conducted at 75°F and 50 pct relative humidity.

### Rate of Loading

Specimens from board types 4, 7, and 11 were tested in the rate of loading portion of the study. Tension specimens from board type 11 with aligned face flakes were cut from the panels parallel to flake alignment only. Bending specimens for board type 11 were cut both parallel (  $\parallel$  ) to and perpendicular (  $\perp$  ) to face flake alignment. Table 2 shows rates of loading used and the number of specimens of each type tested at the different rates. Except for rates of loading, test methods followed requirements in ASTM D1037-78 (American Standard for Testing and Materials 1978).

### Duration of Load

All four board types were included in the duration-of-load portion of the study. Specimens were loaded in tension parallel to surface. Specimens for board type 11 were cut from the panel parallel to flake alignment. Ten control specimens of each board type were loaded to failure at the ASTM specified rate of 0.15 in per min. The original plan called for two specimens of each board type to be loaded at constant stress levels of 90, 85, 80, 75, 70, 65, 60, 55, and 50 pct of the strength of side-matched controls. However, because of room humidity control problems, a number of specimens had to be culled. The number of specimens actually under load till failure at the different stress levels were as follows:

<u>Stress level (pct)</u>	<u>Number of specimens</u>
90	7
85	7
80	16
75	3
70	0
65	12
60 (59.4, actual)	1
55	0
50	9 <sup>1</sup>
TOTAL	55

Seven additional specimens failed during loading; 4 at 90 pct stress level and one each at 85, 75, and 70.

Control specimens were loaded to failure in a mechanical screw-type universal testing machine at a constant rate of deformation of 0.15-in per min. Times to failure for the control specimens ranged from about 1-1/2 to 5 min. The same bolted-on tension grips (fig. 1) were used on both the control and constant-load specimens. Figure 1 shows the steel frames used to apply constant loads. Specimens were loaded in about 2 s by lowering the support post under the lever arm. The digital clock was attached to a microswitch attached to the support post.

<sup>1</sup>Two of the nine specimens survived the 3-1 2-yr loading period.

**Table 2.—Test machine crosshead speed used on flakeboard rate of loading specimens<sup>a</sup>**

Board type	Head speed				
	Slow	Medium slow	Control (ASTM) <sup>b</sup>	Medium fast	Fast
	----- in min -----				
STATIC BENDING					
4, 7, 11 ▮	0.005(4)	0.02(4)	0.24(12)	3.0(4)	14.0(4)
11 ▮	.005(3)	.02(3)	.24(7)	3.0(3)	14.0(3)
TENSION PARALLEL					
4, 7, 11 ▮	.02(4)	.08(4)	.15(12)	1.0(4)	4.0(4)

<sup>a</sup>Numbers in parentheses indicate number of specimens of each board type loaded at each rate.

<sup>b</sup>American Society for Testing and Materials.



**Figure 1.—Lever-arm test frame for applying load to duration-of-load tension specimens. (M 142 926)**

## Results and Discussion

In order to compare results from the study of commercial boards (McNatt 1975), data from this study are presented in the same way as those from that earlier study.

### Rate of Loading

Average modulus of rupture values (MOR), expressed as a percent of control strength, are plotted against time to maximum load (T) in seconds on a logarithmic scale in figure 2. Times to maximum load ranged from 1 to 4,320 s. The least squares regression line through the data was calculated with  $\log_{10} T$  as the independent variable and MOR as the dependent variable. The equation of this straight line is

$$\text{MOR} = 112.1 - 7.9 \log_{10} T \quad (r^2 = 0.70) \quad (1)$$

Average bending modulus of elasticity ( $\text{MOE}_B$ ) data are plotted in figure 3. The regression equation is

$$\text{MOE}_B = 104.0 - 4.3 \log_{10} T \quad (r^2 = 0.55) \quad (2)$$

Average tensile strength and modulus of elasticity ( $\text{MOE}_T$ ) data are plotted in figures 4 and 5 respectively. The regression equations are

$$S_T = 129.4 - 12.3 \log_{10} T \quad (r^2 = 0.53) \quad (3)$$

$$\text{MOE}_T = 111.5 - 5.4 \log_{10} T \quad (r^2 = 0.15) \quad (4)$$

where  $S_T$  is tensile strength.

In equations (2) and (4), T is used only as a reference scale because  $\text{MOE}_B$  and  $\text{MOE}_T$  were calculated using the slope of the lower portion of the load-deformation curves. These two equations should be interpreted as follows (using equation (2) as an example): if a bending specimen is loaded at a rate such that the time required to reach maximum load is increased tenfold,  $\text{MOE}_B$  will decrease an amount equal to about 4 percent of  $\text{MOE}_B$  determined at the standard ASTM rate of loading.

Equations (1) - (4) suggest that flakeboard MOR decreases 8 pct and flakeboard tensile strength decreases 12 pct for each tenfold increase in T, whereas  $\text{MOE}_B$  and  $\text{MOE}_T$  decrease about 4 to 5 pct. The limited data in this study did not point to any obvious differences between the various board types.

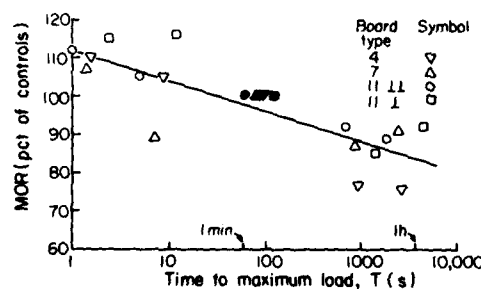


Figure 2.—Effect of rate of loading on modulus of rupture (MOR) of lab-made structural flakeboards. See table 1 for board types. Solid symbols are controls for each board type.  $\square$  = parallel to flake alignment;  $\square$  = perpendicular to flake alignment. (ML85 5069)

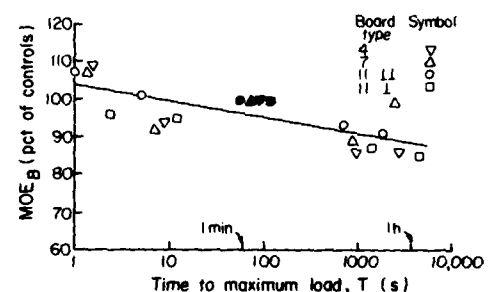


Figure 3.—Effect of rate of loading on bending modulus of elasticity ( $\text{MOE}_B$ ) of lab-made structural flakeboards. See table 1 for board types. Solid symbols are controls for each board type.  $\square$  = parallel to flake alignment;  $\square$  = perpendicular to flake alignment. (ML85 5070)

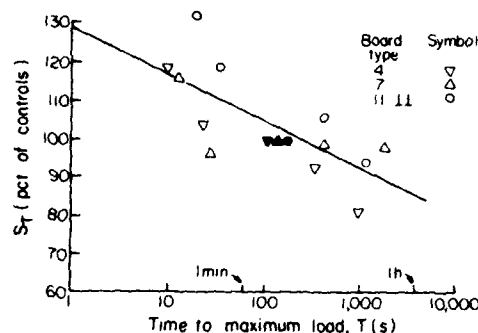


Figure 4.—Effect of rate of loading on tension parallel-to-surface strength ( $S_T$ ) of lab-made structural flakeboards. See table 1 for board types. Solid symbols are controls for each board type.  $\Delta$  parallel to flake alignment. (ML85 5067)

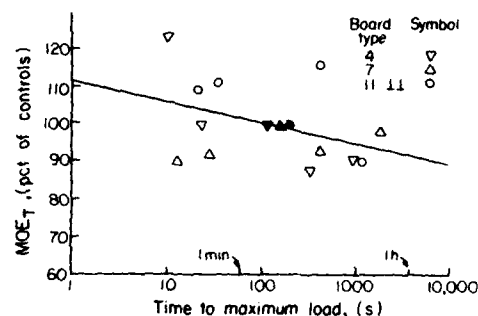


Figure 5.—Effect of rate of loading on tension modulus of elasticity ( $MOE_T$ ) of lab-made structural flakeboards. See table 1 for board types. Solid symbols are controls for each board type.  $\Delta$  parallel to flake alignment. (ML85 5068)

In the earlier study (McNatt 1975), which included four commercial particleboards and one lab-made flakeboard (all urea bonded), MOR decreased 6 pct and tensile strength decreased 9 pct for each tenfold increase in  $T$ . In that study  $MOE_B$  and  $MOE_T$  decreased 6 and 5 pct, respectively.

#### Duration of Load

Time to failure ( $T_F$ ) for the individual tension specimens at different constant stress levels are listed in table 3 and plotted in figure 6.  $T_F$  is plotted on a logarithmic scale as a function of stress level (SL) expressed as a percent of static strength of the control specimens. The regression equation for the straight line through the data was calculated with SL as the independent variable and logarithm of time to failure ( $\log_{10} T_F$ ) as the dependent variable since time to failure depended on the level of stress on the specimen. As originally calculated, the equation is

$$\log_{10} T_F = 10.90 - 0.126 \text{ SL} \quad (r^2 = 0.57) \quad (5)$$

Solving for SL puts it into the form most often used for duration-of-load data:

$$\text{SL} = 86.4 - 7.9 \log_{10} T_F \quad (6)$$

where SL is in percent of strength of control specimens and  $T_F$  is in hours.

Equation (6) is somewhat biased because "time to failure" for two specimens at 50 pct SL is actually time to termination of the tests after 30,000 h (almost 3-1/2 yr). If these could have remained under load till failure, the slope of the regression line would have been somewhat less than 7.9.

Also shown in figure 6 is the regression line determined in the earlier study (McNatt 1975) of three commercial particleboards and one lab-made flakeboard. The method of loading (tension parallel to surface) was the same as that used in this study. The equation for this dotted line is

$$\text{SL} = 84.8 - 8.3 \log_{10} T_F \quad (7)$$

At the 95 pct confidence level slopes and intercepts of equations (6) and (7) are not significantly different.



**Table 3.—Time to failure for flakeboard specimens at constant stress in tension**

Stress level <sup>a</sup>	Board type			
	4	7	8	11
	h			
90	0.0014 <sup>c</sup> 3.9	0.275 1.9	0.1375 <sup>i</sup> —	0.003 <sup>h</sup> .003 <sup>h</sup>
85	3.8 188.8	.1 5.0	3.5 —	.0028 <sup>j</sup> 32.9
80	19.0 70.6 159.0 220.9 —	.0417 <sup>e</sup> 3.8 8.5 37.7 285.5	.283 <sup>g</sup> 16.3 16.7 122.0 —	.0333 <sup>i</sup> 37.1 835.9 — —
75	.0028 <sup>d</sup> —	2.2 46.1	— —	— —
65	1.149.5 2.514.0 4.827.2 —	50.6 1,059.3 10,153.6 15,400.0	4,908.8 — — —	1,292.1 14,019.2 25,849.7 26,355.7
60 <sup>b</sup>	—	—	—	630.7
50	19,356.9 — — —	1,224.0 3,050.0 16,800.0 30,000 + <sup>k</sup>	— — — —	1,109.0 5,546.4 27,354.3 30,000 + <sup>k</sup>

<sup>a</sup>Percent of control.

<sup>b</sup>Actual stress was 59.4 pct of control.

<sup>c</sup>Measured time: 5 s

<sup>d</sup>Measured time: 10 s

<sup>e</sup>Measured time: 2.5 min

<sup>f</sup>Measured time: 8.25 min

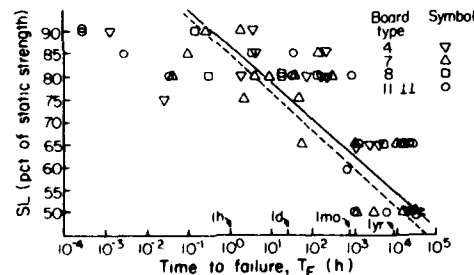
<sup>g</sup>Measured time: 17 min

<sup>h</sup>Measured time: 1 s

<sup>i</sup>Measured time: 10 s

<sup>j</sup>Measured time: 2 min

<sup>k</sup>Specimens had not failed when tests were terminated.



**Figure 6 —Duration of load to failure for four lab-made flakeboards at different levels of constant stress in tension parallel to surface (SL). Solid line represents data in this study. Dotted line represents particleboard data from previous study (McNatt 1975). See table 1 for board types parallel to flake alignment. (ML85 5066)**

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Equation (6) is also essentially the same as one representing the overall duration-of-load performance of particleboard in tension, bending, and shear (McNatt 1978):

$$SL = 83.5 - 8.2 \log_{10} T_F \quad (8)$$

Equation (8) was calculated from the combined data (247 individual test values) of five different studies (Bryan 1960; Kufner 1970; Lundgren 1969; McNatt 1975, 1978).

## Summary and Conclusions

Three different lab-made flakeboards, one with aligned face flakes, were tested in bending and tension at different rates of loading. Strength decreased 8 pct for MOR and 12 pct for tensile strength for each tenfold increase in  $T$ .  $MOE_B$  and  $MOE_T$  decreased 4 to 5 pct. This is similar to previously reported information for commercial particleboards made primarily from planer shavings and sawdust.

These same three flakeboards, plus one additional one with aligned flakes throughout, were loaded till failure in tension at different constant stress levels between 50 and 90 pct of the static strength of control specimens.  $T_F$  increased tenfold for each 8 pct decrease in stress level. This is essentially the same percent decrease found previously for commercial particleboards.

The conclusion from this study is that flakeboards behave similar to conventional particleboards under different rates of loading and different levels of constant stress when values are expressed as a percent of the static strength of the material.

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